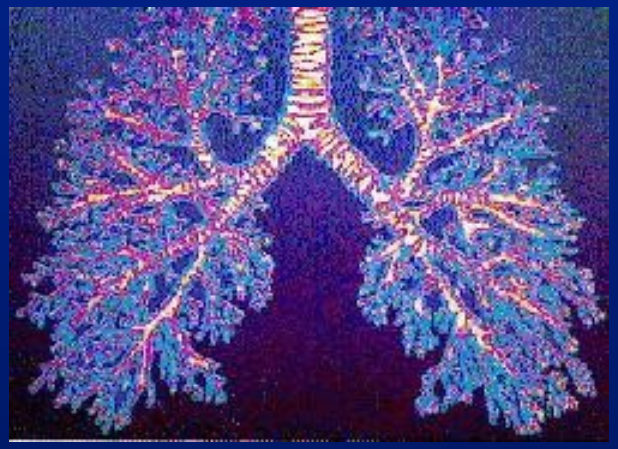
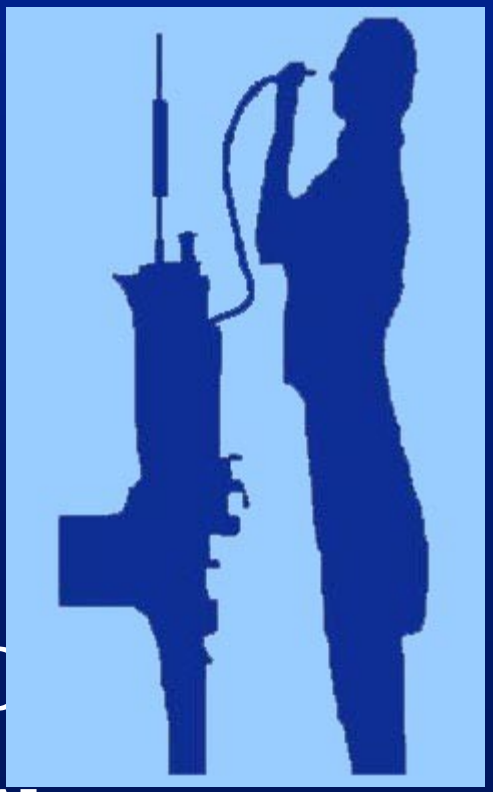
# Pulmonary Function Testing





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# Overview

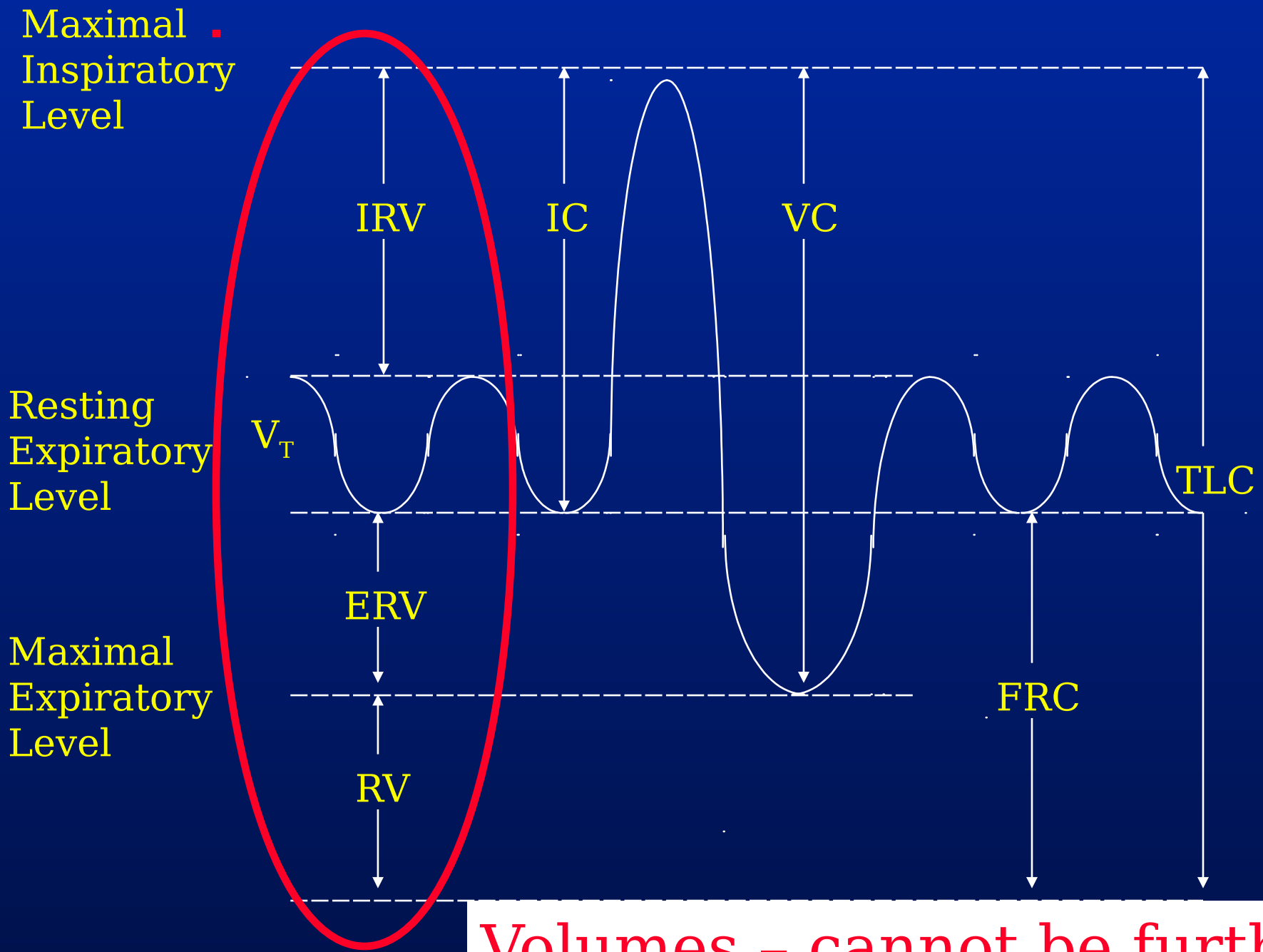
- Accepted Uses
- Lung Volumes/Capacities
- Spirometry
- Interpretation of Spirometry
- Patterns of Spirometry in Airway Obstruction
- Bronchodilator Response
- Bronchoprovocation
- Other PFTs: DLCO, ABG, MIP/MAP
- Referencees

# Accepted Uses

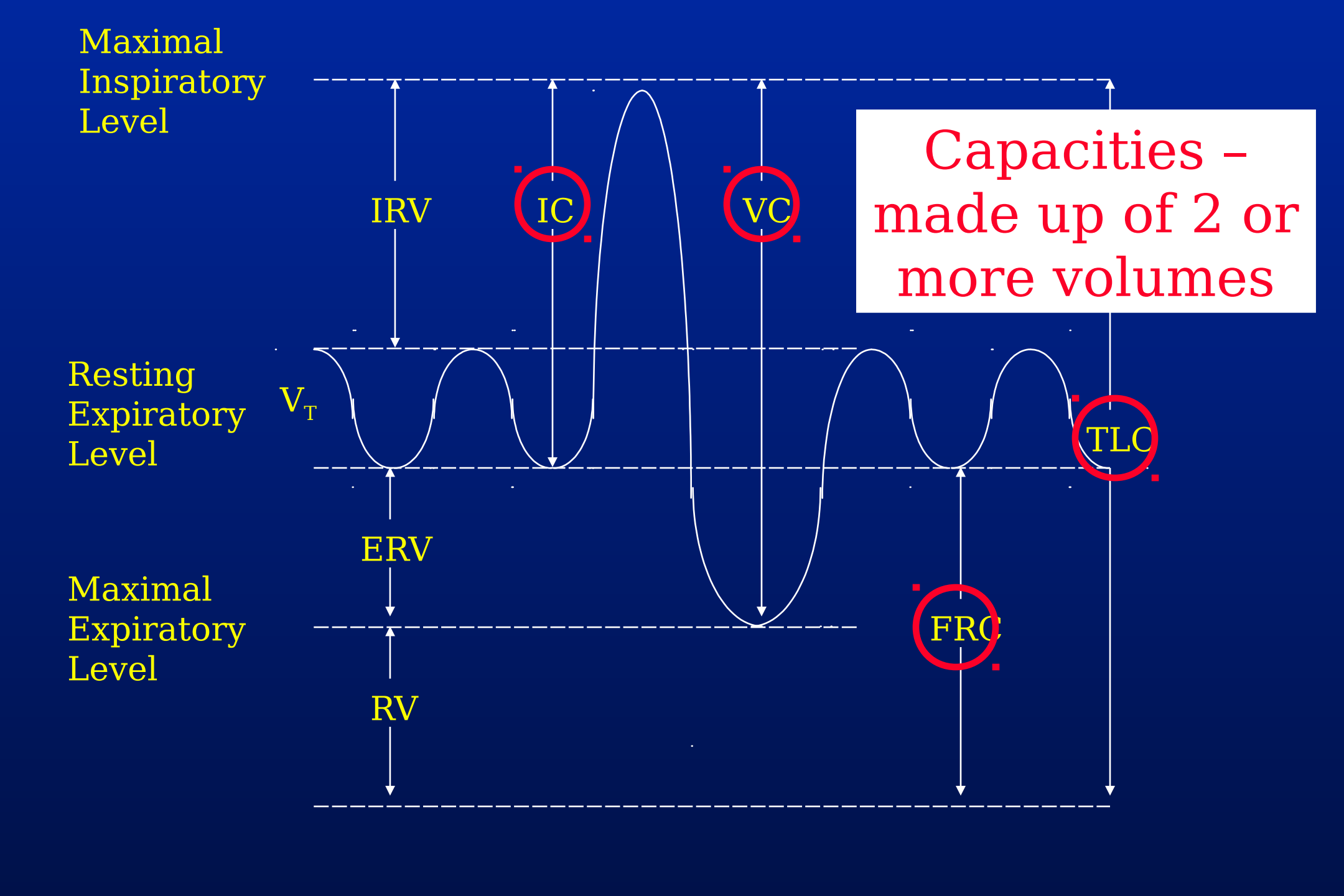
- Establish a diagnosis and estimate prognosis
- Follow course of disease
- Assess response to therapy
- Assess preoperative risk in selected patients
- Determination of subclinical abnormalities in high-risk patients
  - Smokers, occupational exposure, predisposing illnesses

# Pulmonary Function Testing

- Spirometry - air movement
- Lung volumes - compartment sizes
- Bronchoprovocation
- Reversibility testing
- Diffusing capacity
- Arterial blood gases
- Maximal Respiratory Pressures

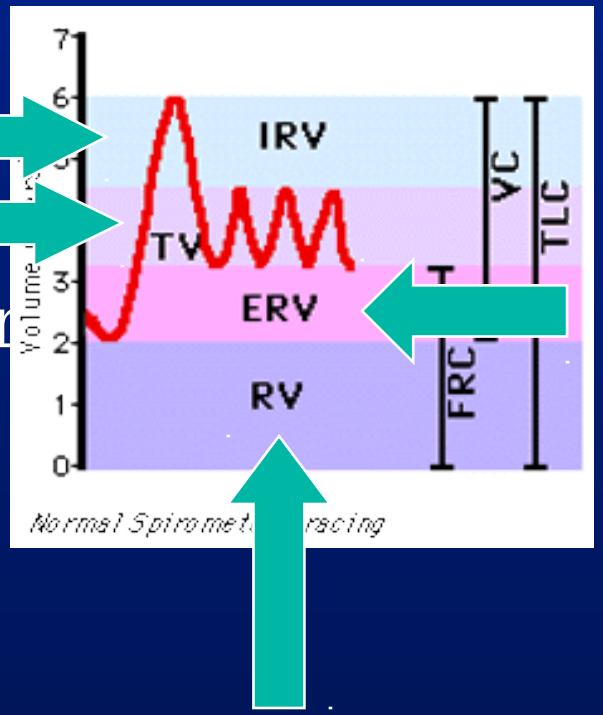



Volumes – cannot be further divi


Maximal Inspiratory Level
IRV
IC
VC
Capacities – made up of 2 or more volumes
Resting Expiratory Level
$V_T$
TLC
ERV
Maximal Expiratory Level
FRC
RV

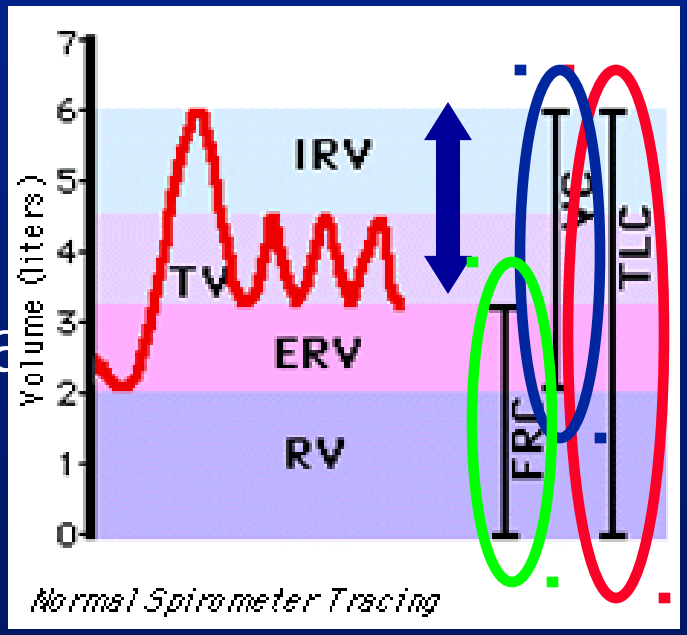
# Lung Volumes

- Tidal Volume ($V_T$)
  - Volume inhaled/exhaled in normal breathing
- Inspiratory Reserve Volume (IRV)
  - Max inspired volume from inspiration
- Expiratory Reserve Volume (ERV)
  - Max exhaled volume from end-expiration
- Residual Volume (RV)
  - Volume remaining after max exhalation



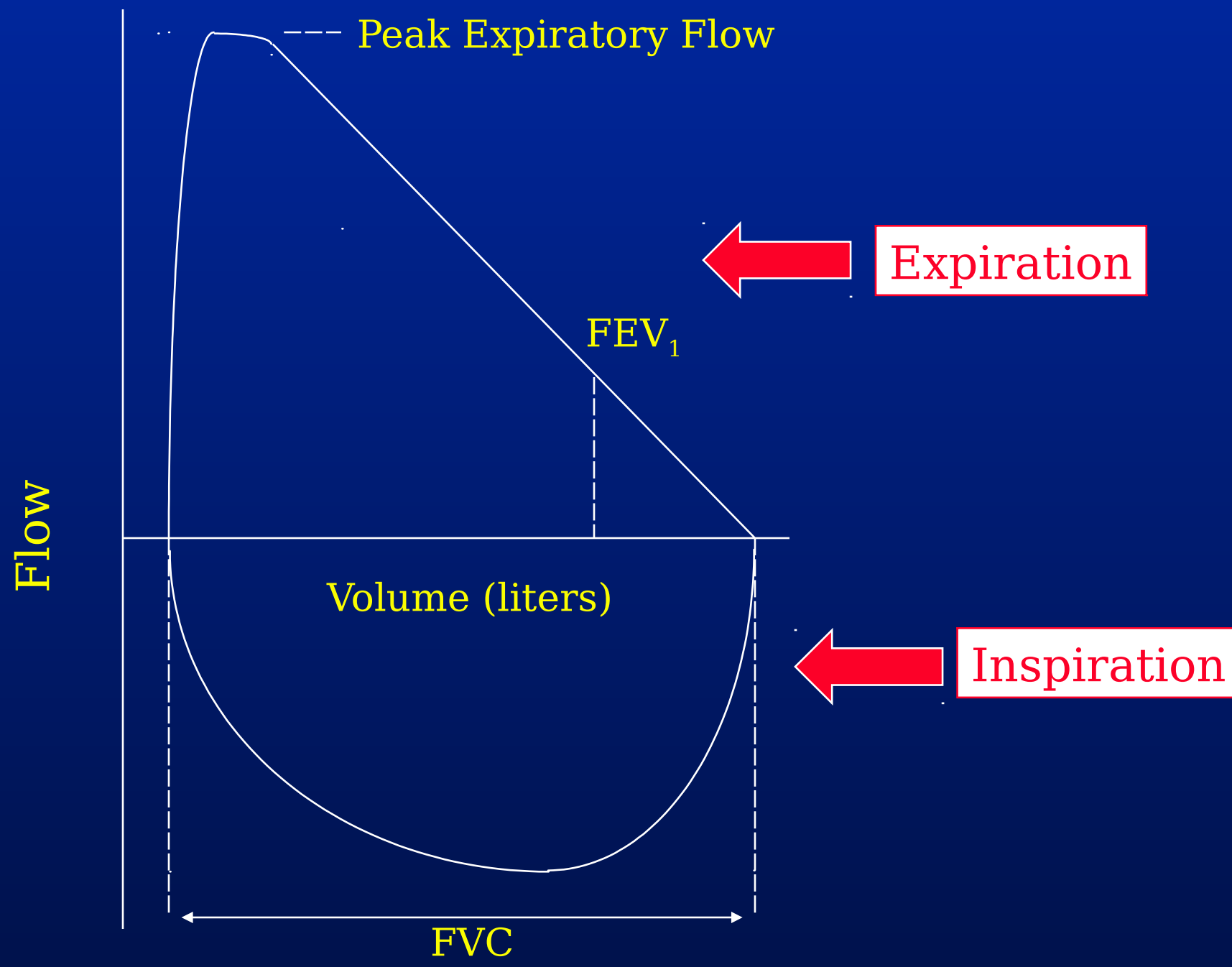
# Lung Capacities

- Total Lung Capacity (TLC)
  - Amount of gas in lungs at max inspiration
- Vital Capacity (VC)
  - Amount of gas expelled after ma inspiration
- Inspiratory Capacity (IC)
  - Max volume gas inspired from resting expiration
- Functional Residual Capacity (FRC)
  - volume of gas at resting expiration



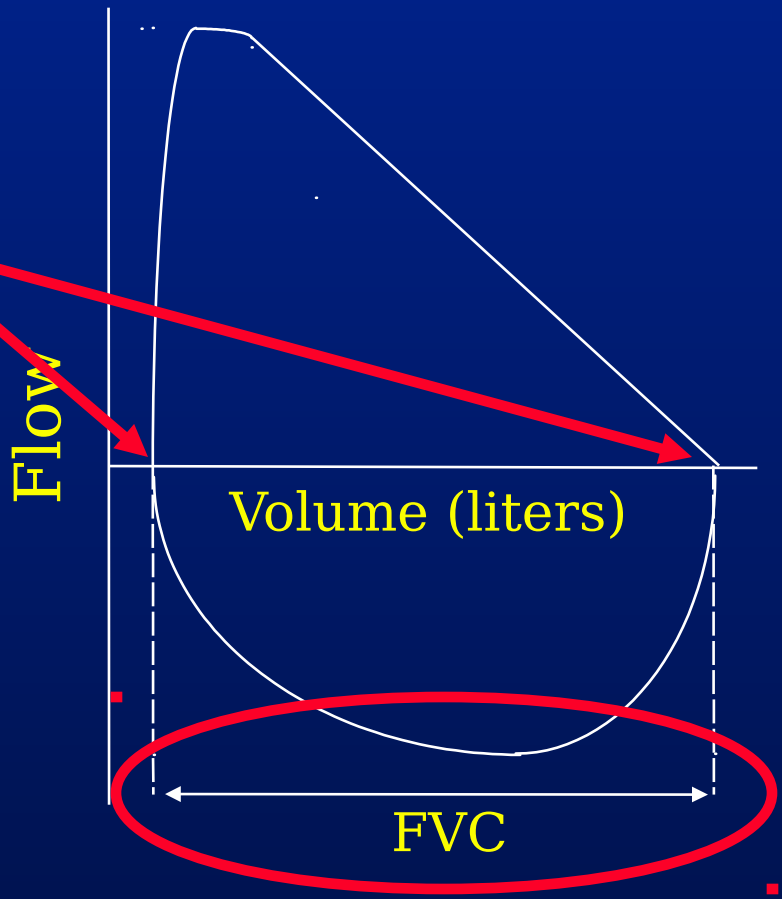
# Spirometry

- FVC
- $FEV_1$
- $FEV_1$/FVC ratio
- $FEF_{25-75}$
- PEFR
- Flow vs. volume loop
- Volume vs. time curve


Peak Expiratory Flow
Expiration
FEV1
Flow
Volume (liters)
Inspiration
FVC

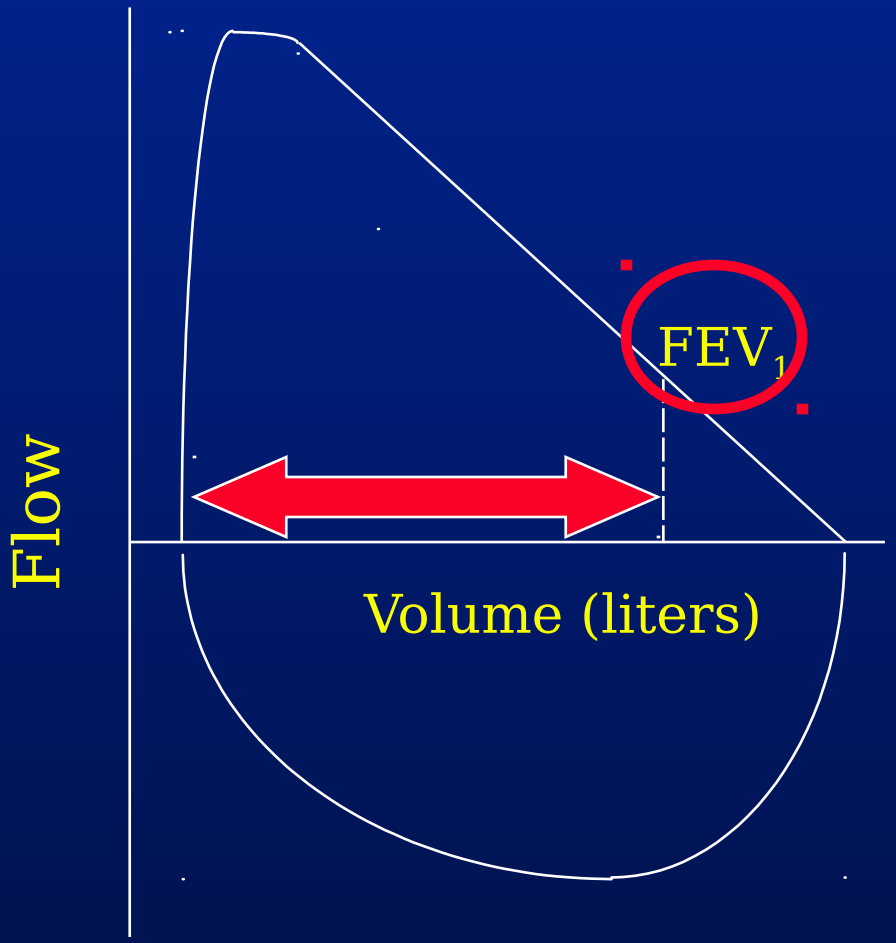
# Forced Vital Capacity

- Full inspiration to TLC
- Rapid, forceful maximum expiration to RV
- Effort dependent
- Differs from Slow Vital Capacity
  - Slow VC may be greater with obstruction
- Normal > 80%



# FEV1

- Volume of air expired in first second
- Based on same FVC maneuver
- Very effort dependent
- Determines severity of obstructive disease
  - Asthma
  - COPD
- Normal > 80%



# FEV1/FVC

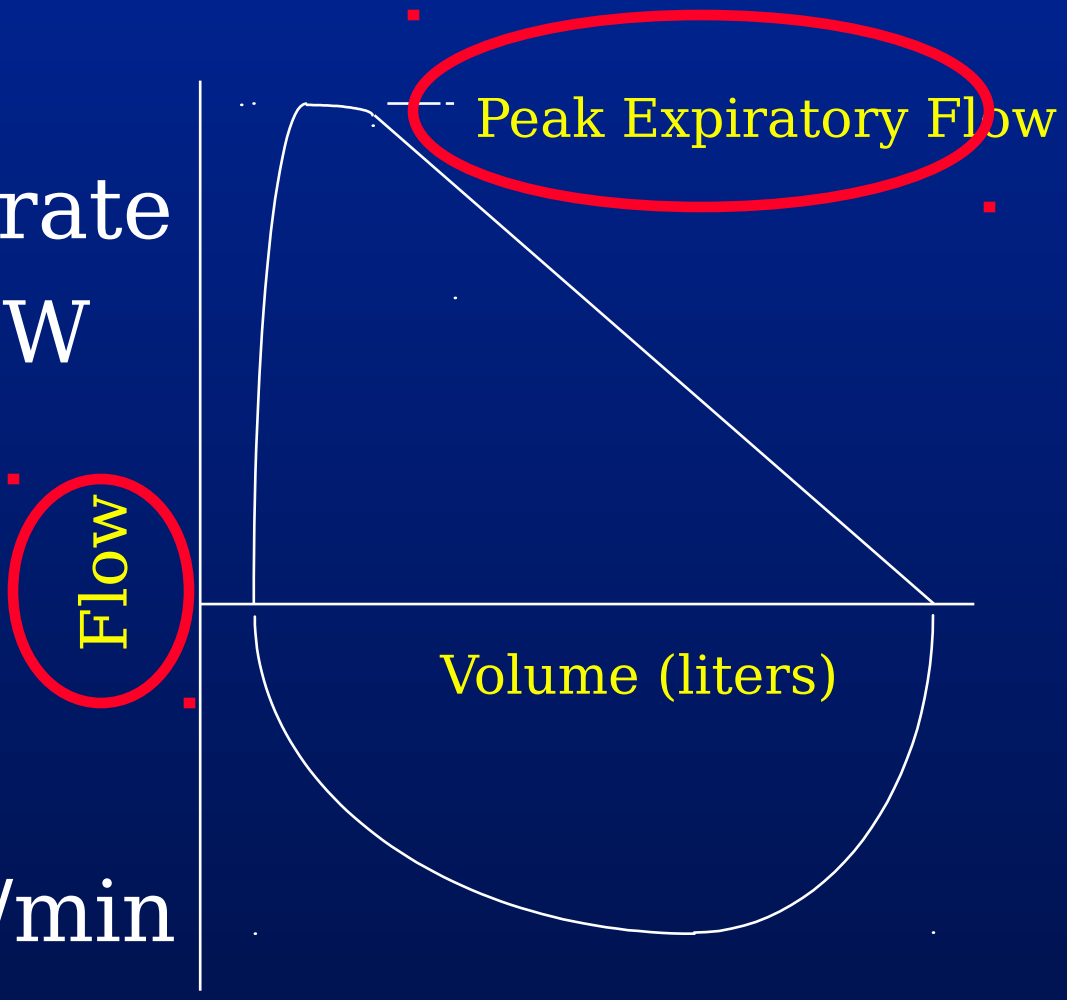
- Ratio using the absolute numbers for FEV1 and FVC
- Most sensitive measure of obstruction
- Normal  > 70%
  - i.e. a “normal” person should be able to exhale most (>70%) of the air in their lungs within the first second
- Severity of obstruction determined by FEV1

# FEF 25-75%

- Mean forced expiratory flow rate between 25% and 75% of the expired vital capacity
- Rate of air flow during the middle of the test
  - AKA “midflows”
- Reflects air flow in the peripheral or small airways
  - Less sensitive and specific
  - Largely effort independent
- Normal  > 50%

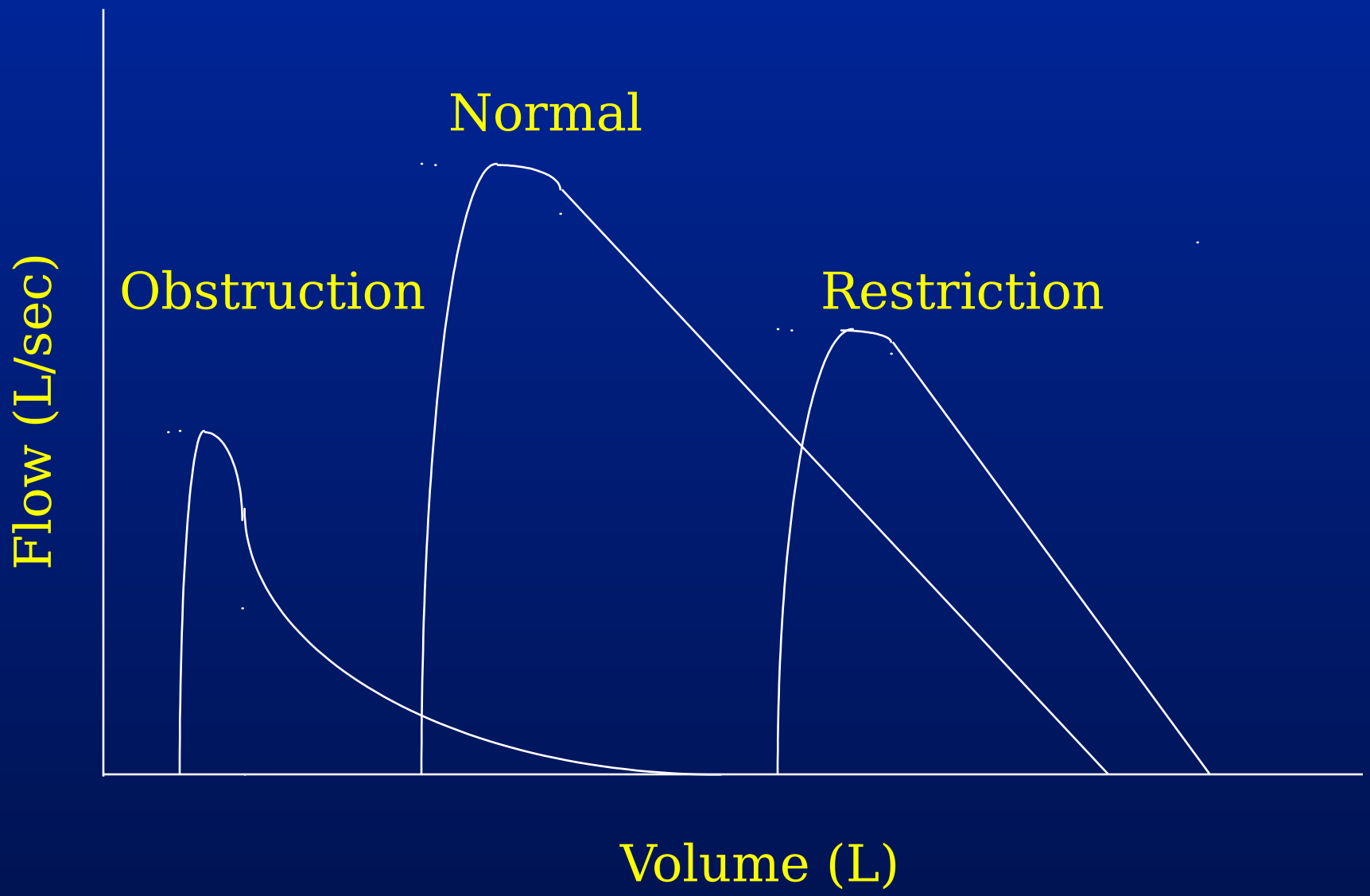
# PEFR

- Peak expiratory flow rate
- Measurement of FLOW not volume
- Effort dependent
- Measured in L/sec
- Handheld peak flow meter measured in L/min

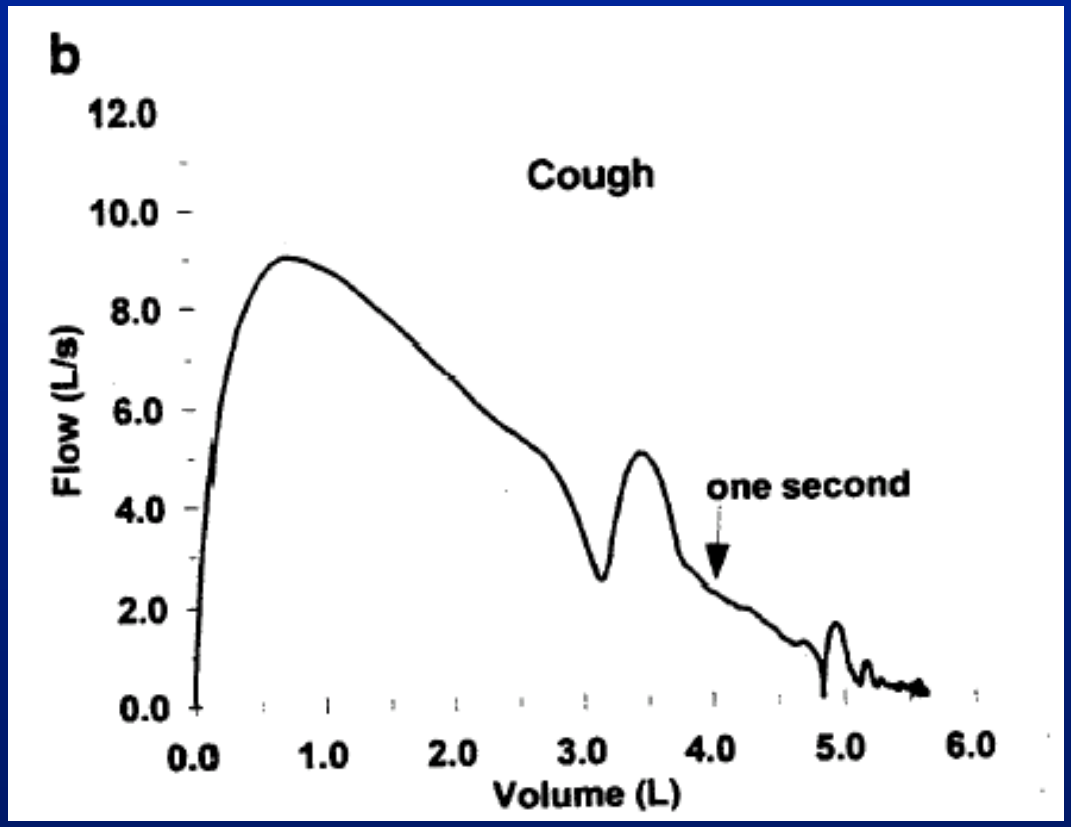


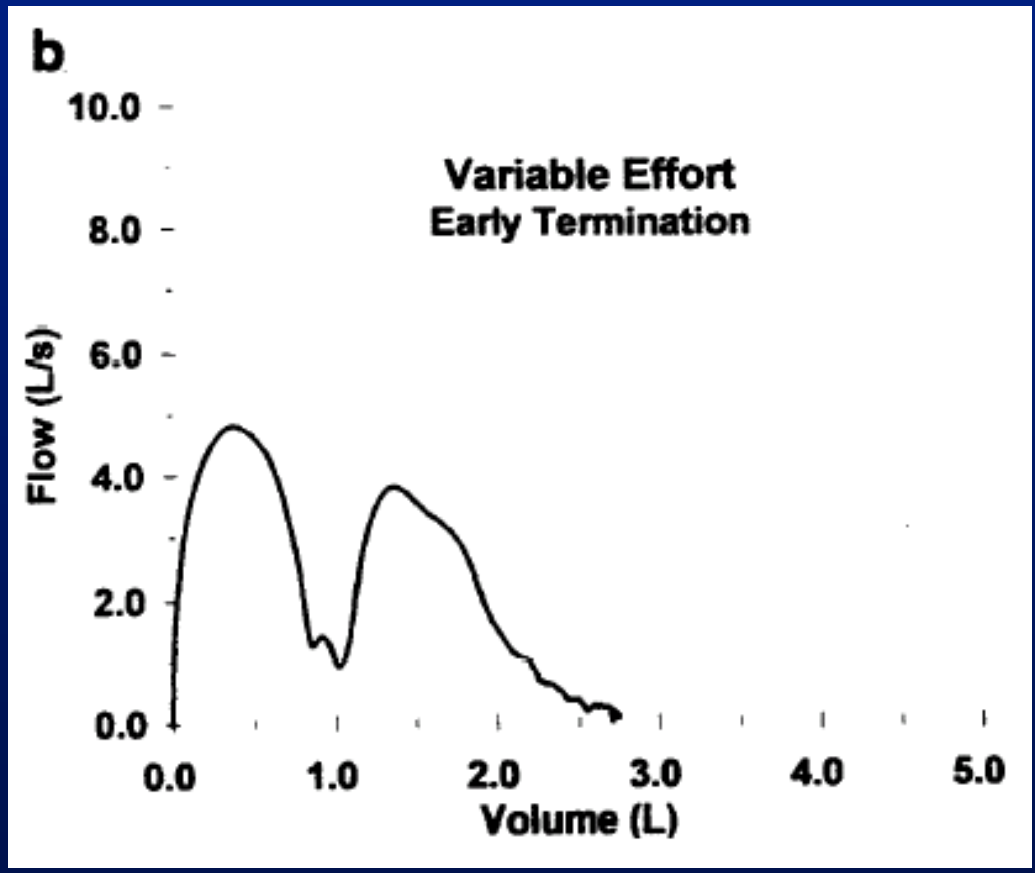
# Flow-Volume Loops

- Enable recognition of characteristic patterns of abnormalities
  - Scooping in obstruction
- Allow recognition of poor effort or mistakes
  - Coughing

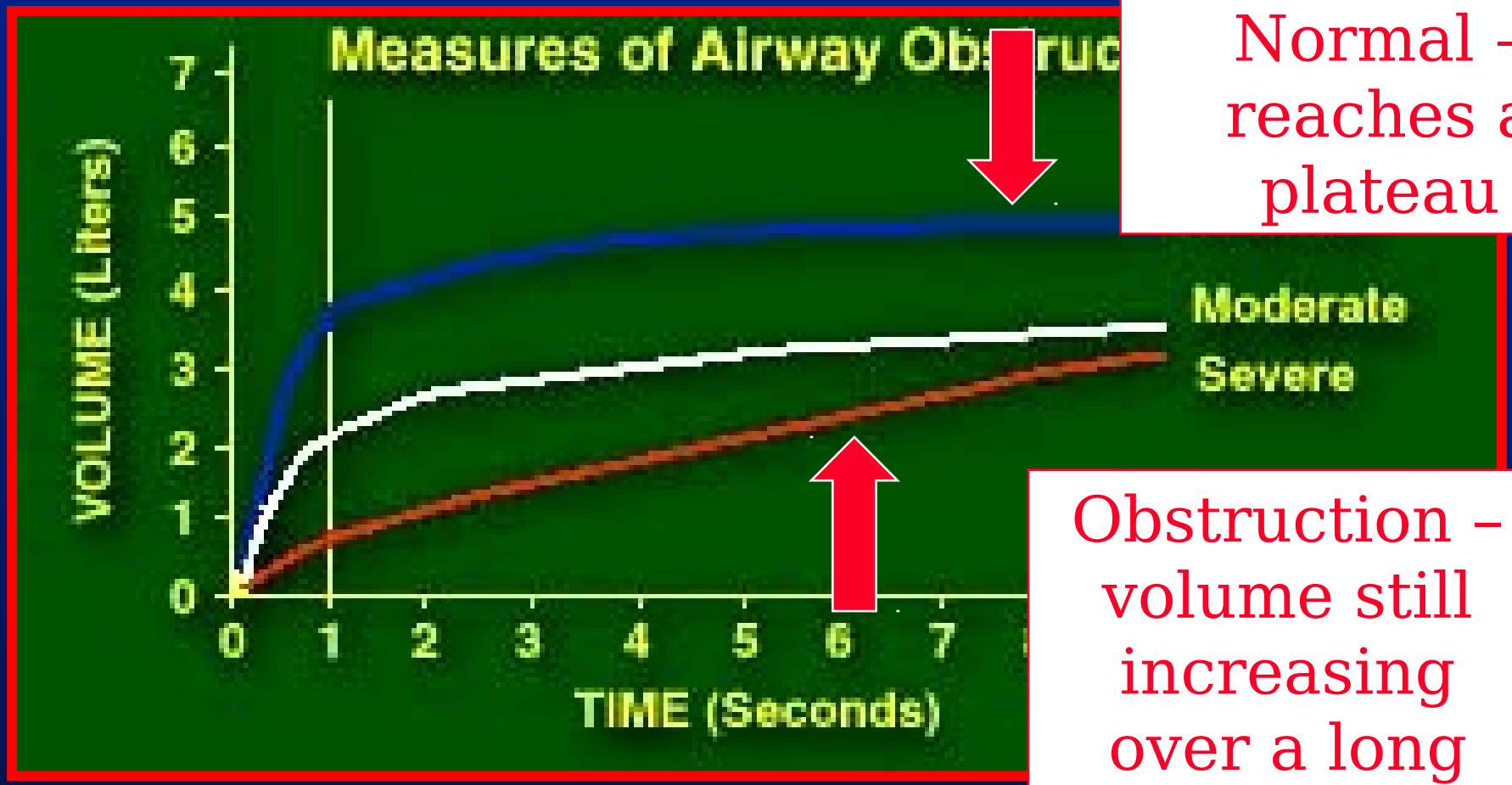

Normal
Obstruction
Restriction
Flow (L/sec)
Volume (L)

# Unacceptable Efforts



# Volume vs. Time Curve




Normal – reaches a plateau

Obstruction – volume still increasing over a long period of time

# Performing Spirometry

- Requirements
  - 3 acceptable tests
  - Full inhalation before start of test
  - Timed start of exhalation
  - Full effort and exhalation
  - Effort free of cough or mouth leaks
  - 6 second duration minimum
- Trained, reliable technician essential

# Spirometry - Assessment

- Assess reproducibility
  - Two highest FVC and FEV1 should be within 5% or 0.1 liter of each other
- If not met, continue testing
  - No more than 8 trials
- Flow/volume loop smooth without notching
- Report 3 best trials

# Spirometry - % Predicted

- Reported results
  - Absolute values for individual
  - Percent predicted based on age, gender, ethnic background and height
- Use consistent reference groups
  - i.e. Knudson, Crapo, NHANES III

ESTIMATES OF THE PROPORTION OF MEASURED BETWEEN-INDIVIDUAL VARIATION IN FEV, OR FVC IN ADULTS ATTRIBUTABLE TO IDENTIFIED FACTORS*

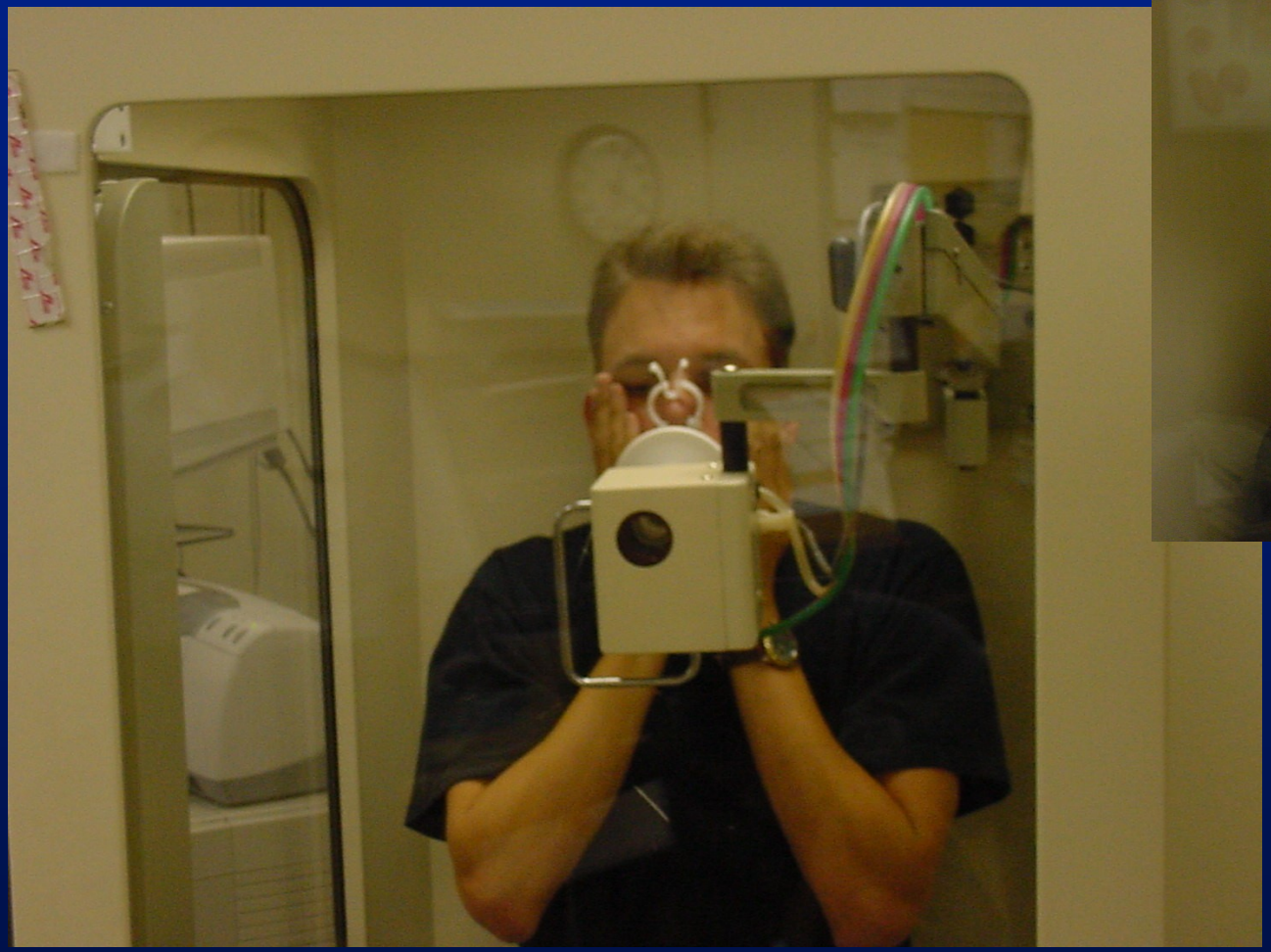
| Factor | | Proportion of Variation Attributable |
|---|---|---|
| Sex | | up to 0.30 |
| Age | 0.08 | |
| Height | 0.20 | up to 0.30 |
| Weight | 0.02 | |
| Ethnic differences | | 0.10 |
| Technical | | 0.03 |
| Unexplained† | | 0.27 |
| Total | | 1.00 |

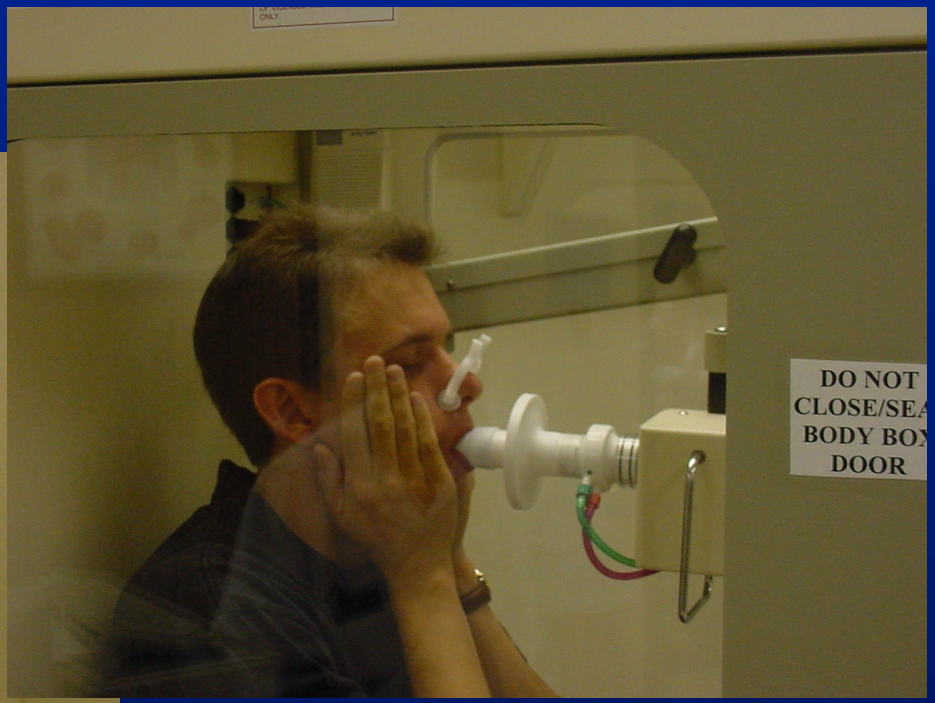
# What doesn't spirometry give you?

## Residual Volume

- Spirometry incapable of measuring RV
  - Also FRC and TLC because they include RV
  - Measuring any one allows calculation of others
- Methods for determining RV
  - Closed-circuit helium dilution
  - Whole body plethysmography
    - Utilizes Boyle's Law ($\mathbf{P_1V_1=P_2V_2}$) for more accurate volume calculation

# Full Lung Volumes





# Interpretation – Obstructive Disease

- First step: FEV1/FVC ratio
- Obstructive defect is present with a reduced FEV1/FVC ratio (<0.70)
  - But may be normal in combined picture
- Second step: FEV1
- Use FEV1 to classify severity of obstruction
- Determine response to bronchodilator

# Obstructive Disease

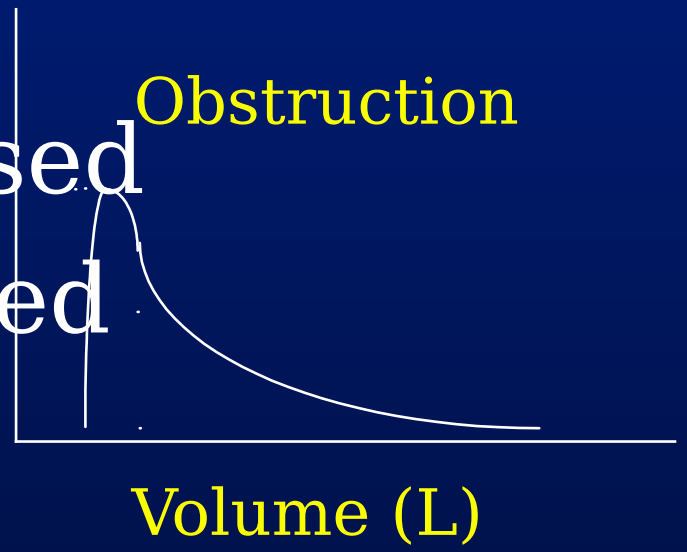
| | $FEV_1$ |
|---|---|
| normal | ≥ 80% |
| mild | 66-79% |
| moderate | 50-65% |
| severe | < 50% |

# Hyperinflation
# -from Full Lung Volumes

| | TLC or RV |
|---|---|
| normal | < 120% |
| mild | 121-134% |
| moderate | 135-149% |
| severe | > 150% |

# Obstructive Lung Disease

- FVC Normal or decreased
- FEV1 Decreased
- FEV1/FVC Decreased
- TLC or RV Increased



# Interpretation – Restrictive Disease

- Step 3: FVC
- Restrictive pattern suggested if FVC is reduced and FEV1/FVC ratio is normal
  - In presence of moderate to severe obstruction, restriction can not be identified
- Definitive diagnosis of restriction requires measurement of lung volumes
- Severity based on TLC or VC

# Restrictive Disease

| | FVC or TLC |
|---|---|
| normal | ≥ 80% |
| mild | 66-79% |
| moderate | 50-65% |
| severe | < 50% |

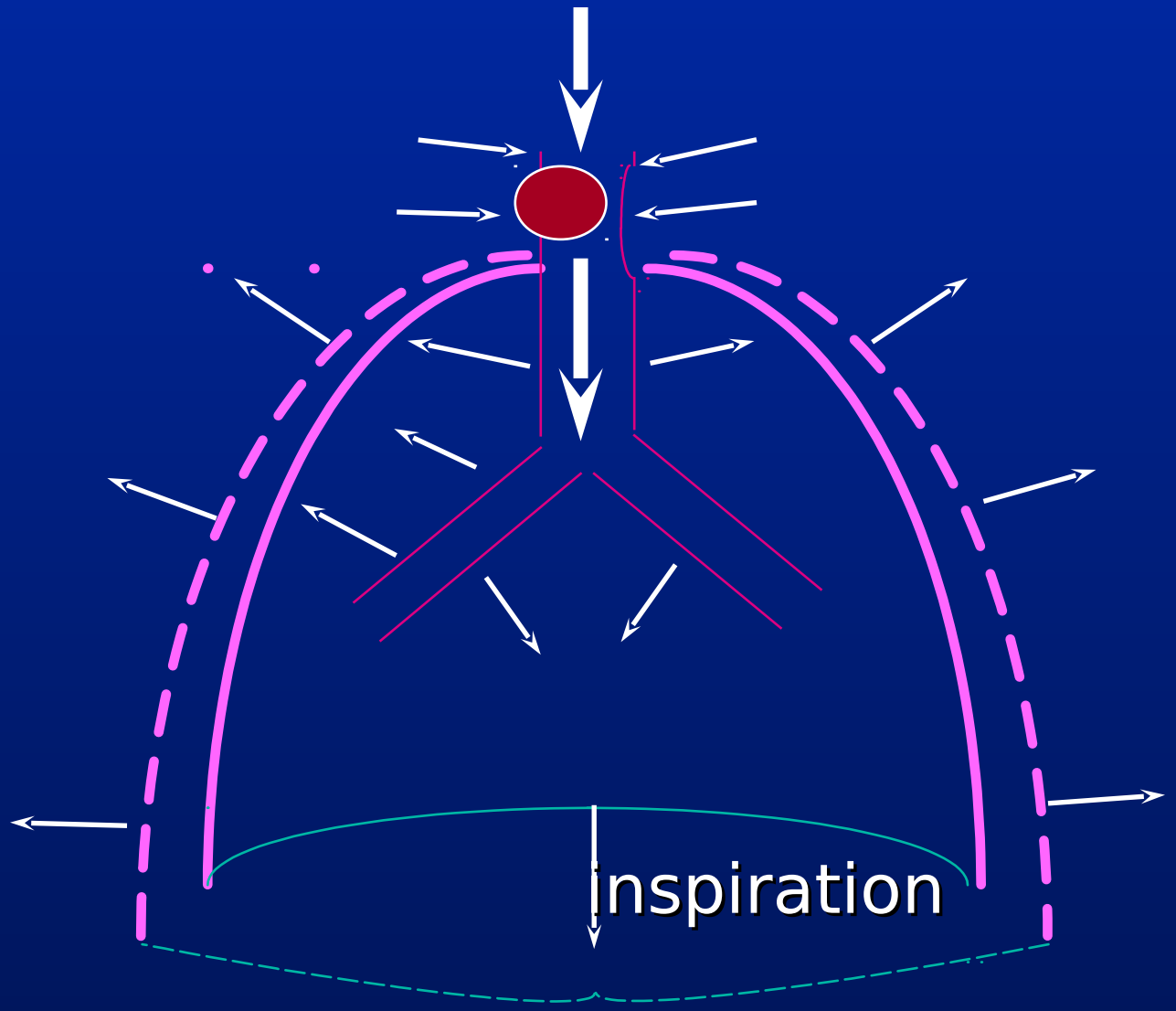
# Restrictive Lung Disease

- FVC Decreased
- FEV1 Normal or decreased
- FEV1/FVC Normal or increased
- TLC or RV Decreased

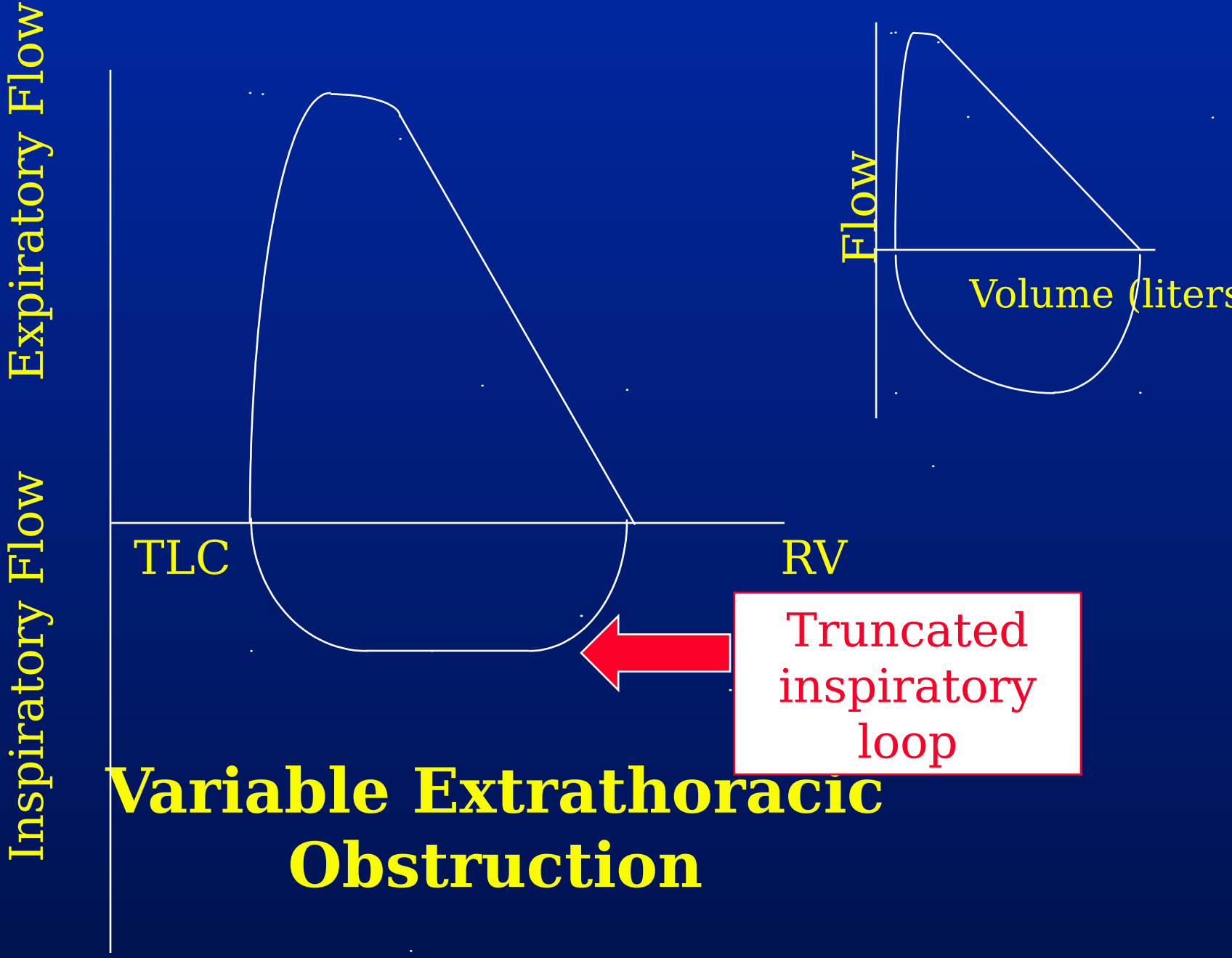
*Need full lung volumes

# Other Things You Can See With Spirometry: Airway Obstruction

- Flow vs. volume loops important
- Types:
  - Variable extrathoracic
  - Variable intrathoracic
  - Fixed obstruction: extrathoracic or intrathoracic



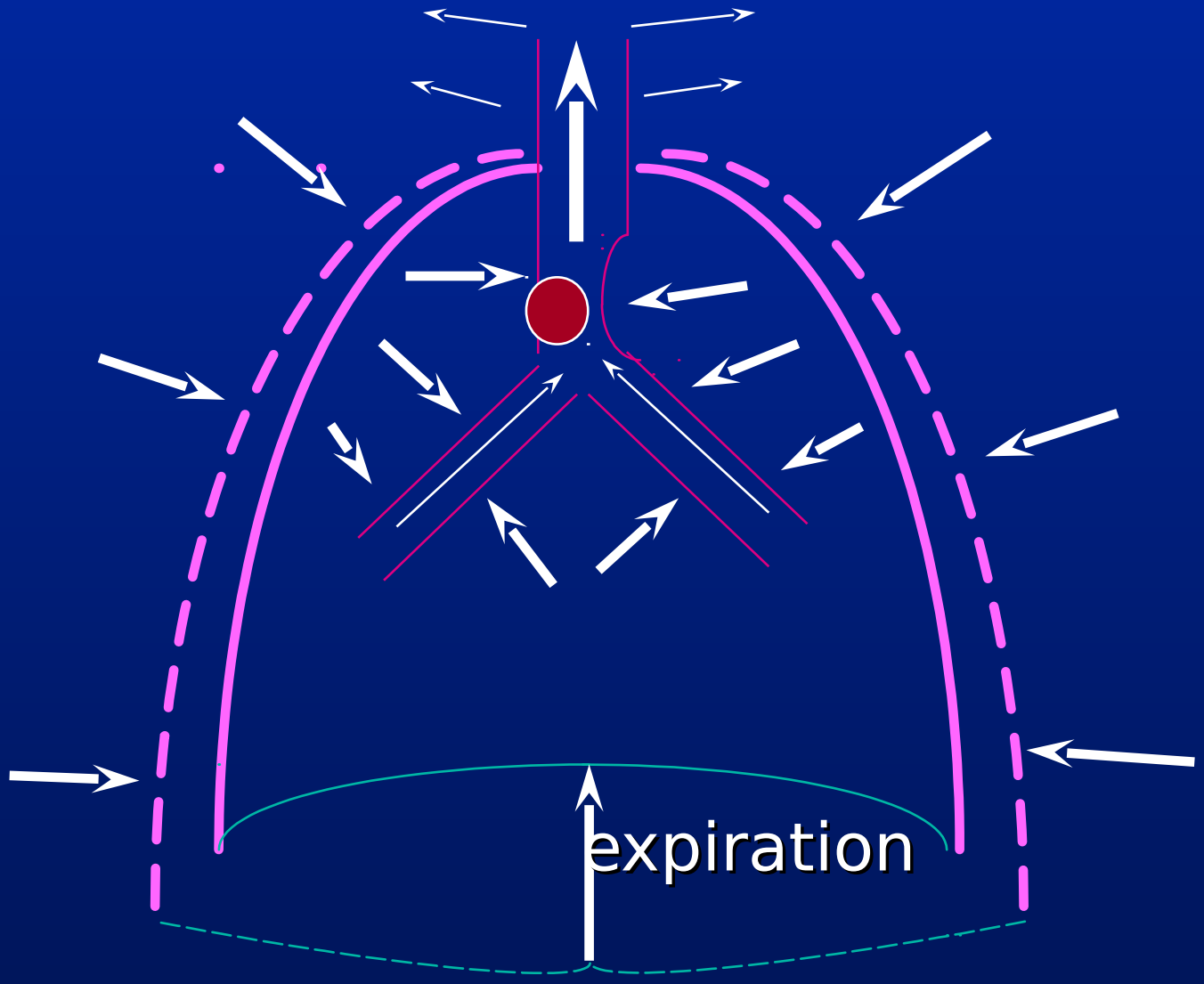

# Variable Extrathoracic Obstruction




# Variable Extrathoracic Obstruction

# Variable Extrathoracic Obstruction

- Flattening of the inspiratory portion of the loop
- Associated conditions
  - vocal cord dysfunction
  - tracheomalacia
  - neoplasm




# Variable Intrathoracic Obstruction

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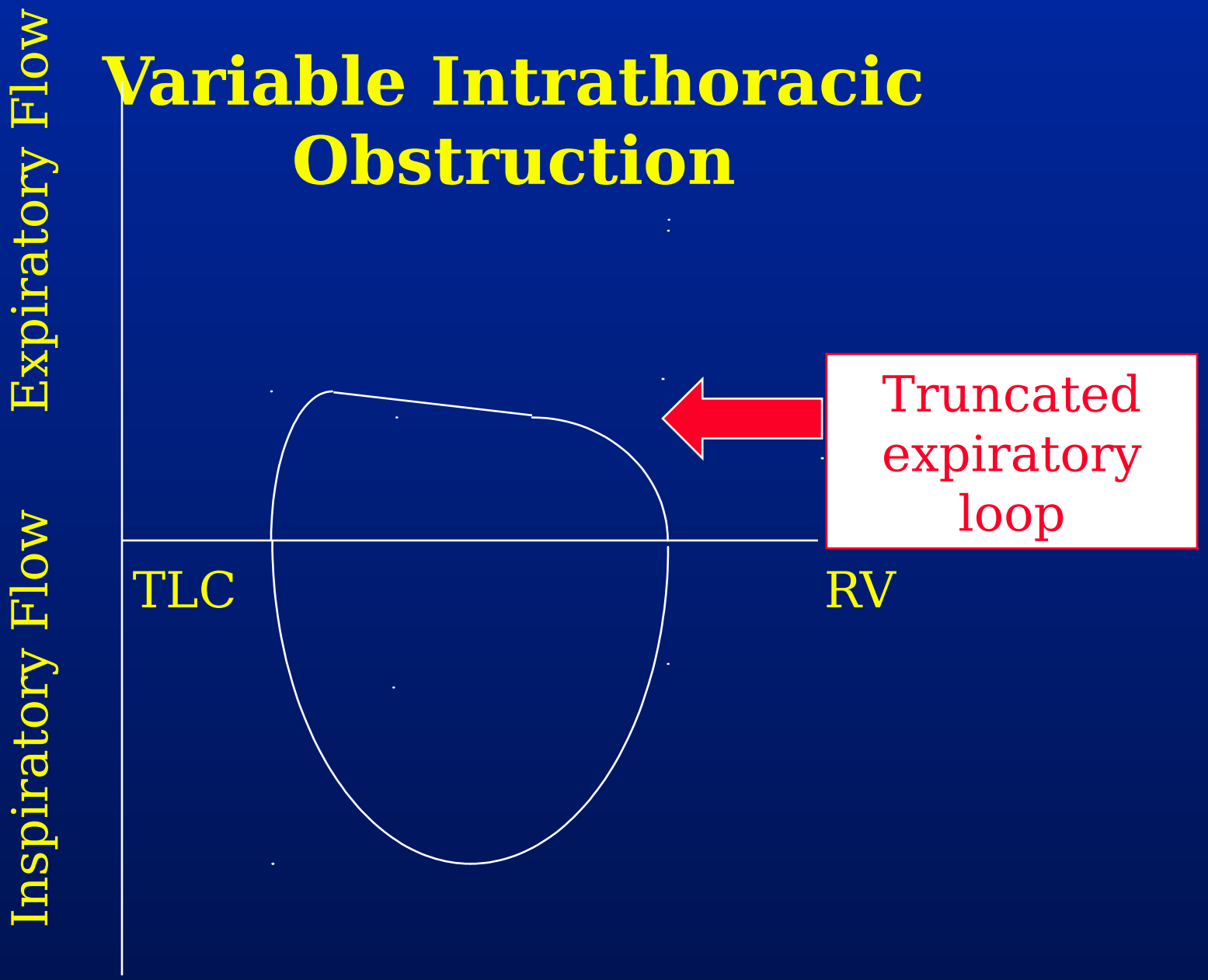
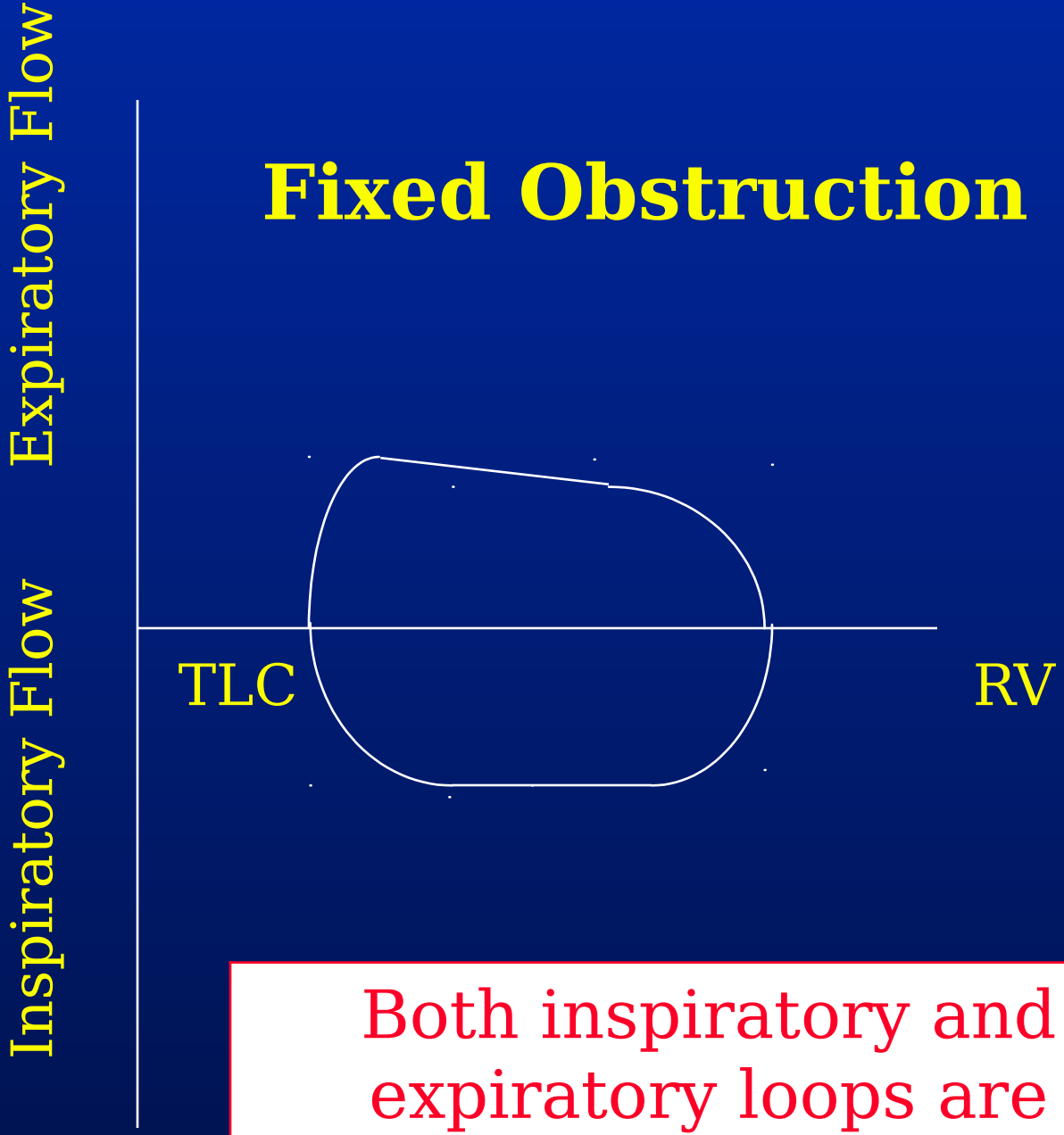


# Variable Intrathoracic Obstruction

- Flattening of the expiratory portion of the loop
- Associated conditions
  - tracheomalacia
  - neoplasm

# Fixed Obstruction



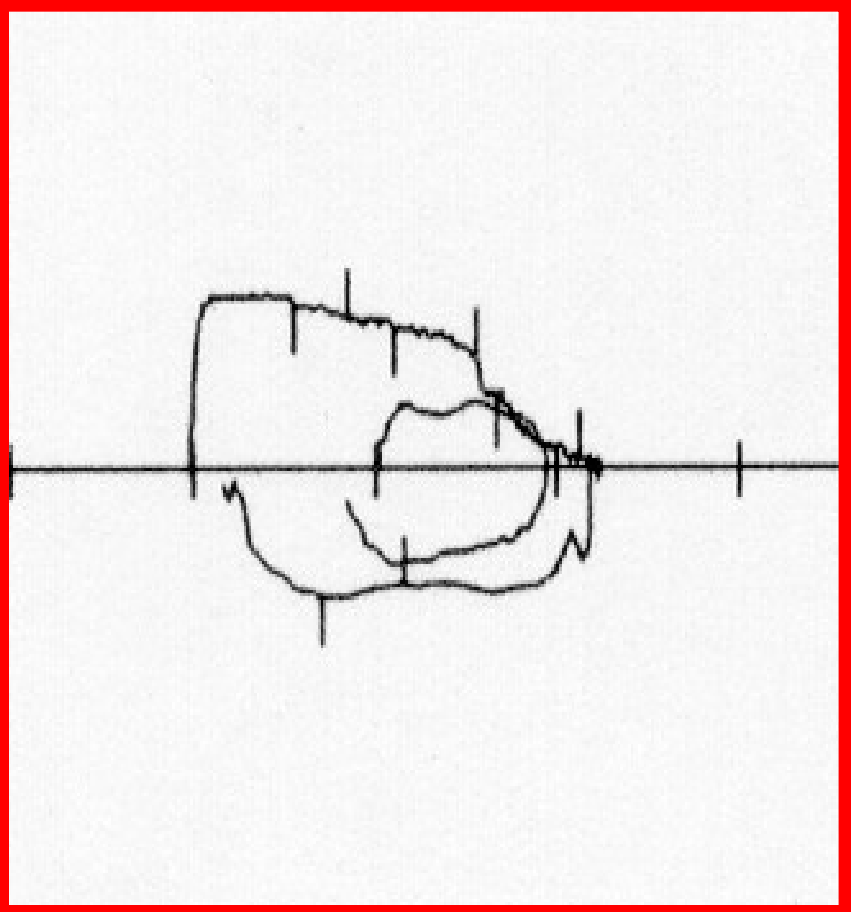

Both inspiratory and expiratory loops are flattened

# Fixed Obstruction (Intra/Extrathoracic)

- Flattening of both inspiratory and expiratory portions of the loop
- Associated conditions
  - Tracheal stenosis
  - Foreign body aspiration
  - Neoplasm

# Fixed Obstruction (Intra/Extrathoracic)

Hypoglottic tracheal stenosis from thyromegaly



# Bronchodilator Methods

- Used to assess reversibility of disease
- Hold bronchodilators prior to testing
- Baseline spirometry
- Administer bronchodilator
  - Nebulizer
  - MDI
- Repeat spirometry in 15-30 minutes

# Interpretation

- ATS recommendations for positive response
  - 12% increase in FEV1
  - absolute increase of 200 ml
- Other standards recommend 15% as cut-off
  - Air Force

# Bronchodilator Response

- Positive response
  - Supports reversible component
  - Therapy with bronchodilator
- Negative response
  - Does not rule out therapy with bronchodilator
  - Baseline test may not improve but still may have exacerbations that require bronchdilator

# Bronchoprovocation

- Tests of bronchial hyperresponsiveness
- Nonspecific bronchoprovacation
  - Incremental increases in methacholine or histamine
  - Positive test: >20% drop in FEV1 at ≤ 8 mg/ml histamine or methacholine ($PC_{20}$ ≤ 8 mg/ml)
- Exercise challenge
  - 80-90% max HR for 4-8 minutes
  - Spirometry performed after exercise
  - Positive test: 15% fall in FEV1

Physician:
Technician: lnm

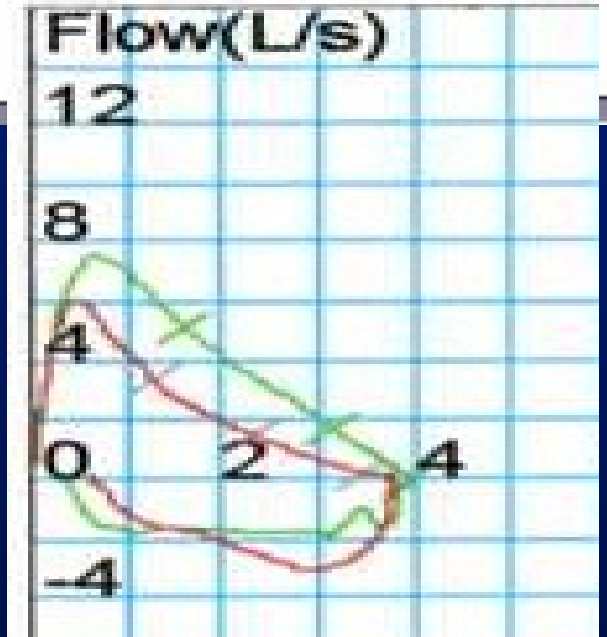
Dosage protocol: WHMC Methacholine
Challenge agent:

Test series date/time: 1/31/2005 07:20 AM
Reference stage: Base

## Results

| Stage | FVC | %Prd | FEV1 | %Prd | FEV1/FVC | %Prd | FEF25-75% | %Prd |
|---|---|---|---|---|---|---|---|---|
| Base | 3.94 | 112% | 3.48 | 110% | 0.88 | 102% | 3.91 | 106% |

| | FVC | %Chg | FEV1 | %Chg | FEV1/FVC | %Chg | FEF25-75% | %Chg |
|---|---|---|---|---|---|---|---|---|
| 0.0625 mg/ml | 4.00 | 2% | 3.53 | 1% | 0.88 | 0% | 3.89 | 0% |
| 0.25 mg/ml | 3.88 | -2% | 3.02 | -13% | 0.78 | -12% | 2.63 | -33% |
| 1 mg/ml | 3.75 | -5% | 2.63 | -24% | 0.70 | -21% | 1.83 | -53% |
| 4 mg/ml | --- | --- | --- | --- | --- | --- | --- | --- |
| 8 mg/ml | --- | --- | --- | --- | --- | --- | --- | --- |
| Post-BD | 3.68 | -7% | 3.32 | -5% | 0.90 | 2% | 4.55 | 16% |



# DLCO

- Diffusing capacity for CO
- Amount of gas which enters the blood per minute per mm Hg partial pressure difference between the alveoli and capillaries
  - In English: how well does gas pass through the lung wall and into the bloodstream
- Normalize for hemoglobin

# DLCO

- Sensitive but not specific for interstitial lung disease
- Factors affecting value
  - Blood flow
  - Hemoglobin concentration
  - Thickness of alveoli membrane
  - Gas exchange surface area

# DLCO Increases

- Polycythemia
- Pulmonary hemorrhage
- Disease with increased pulmonary blood flow
  - Asthma
  - Hyperthyroidism
- Left to right shunt

# DLCO Decreases

- Obstructive lung diseases
  - chronic bronchitis
  - emphysema
- Parenchymal lung disease
  - interstitial lung disease
  - sarcoidosis
- Anemia
- Chronic renal failure
- Chronic hemodialysis
- Ethanol use
- Cardiovascular disease
  - acute MI
  - mitral stenosis
  - primary pulmonary hypertension
  - pulmonary edema
  - pulmonary embolism

# DLCO Decreases

- Pulmonary involvement in systemic disease
  - SLE
  - Progressive systemic sclerosis
  - Rheumatoid arthritis
  - Wegener’s granulomatosis
  - Inflammatory bowel disease

# Arterial Blood Gas

- Routine use in asthma probably not essential
- $O_2$ and $CO_2$ measurement may suggest alternate diagnosis in difficult cases
  - COPD
  - Interstitial lung disease
- $PaO_2$ falls with increasing age
  - expected $PaO_2 = 100 - (age/3)$

# Maximal Respiratory Pressures

- Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP)
- Both decreased in:
  - Generalized neuromuscular disease
  - Poor maneuver performance
- MIP selectively reduced in diaphragmatic dysfunction

# Helpful References


American Thoracic Society. Lung function testing: selection of reference values and interpretive strategies. American Review of Respiratory Disease. 144: 1202-18. 1991.

Bosse CG, Criner GJ. Using spirometry in the primary care office. Postgraduate Medicine. 93(5): 122-48. April 1993.

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